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Revised energy levels for the neutral nitrogen atom

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With 2 plates

SUMMARY

By using a pulsed electrodeless discharge as a light source wavelengths have been determined by means of large concave-grating spectrographs for 110 lines of N I in the photographic infrared and 8 lines in the visible. In the vacuum ultraviolet accurate wavelengths for 16 lines between 1745 Å and 1134 Å have been obtained from some old plates. From these data, which include about 50 newly-classified N I lines, the new terms $3d\,^4P$, $3p'\,^2F$, $5p\,^2D$, $3s''\,^2S$, and $3d'\,^2G$ have been established. Improved values have been derived for all levels involved in the present observations. Smoothed wavelengths in the vacuum ultraviolet have been recalculated from the term system.

Observations in the long-wave region

Introduction

Only a few infrared N I lines were previously observed under conditions favourable for precise measurements. The high current arc in air used by Ryde (1927) and Ingram (1929) gives seriously broadened and displaced spectrum lines. Kamiyama & Sugiura (1940), following Merton & Pilley (1925), used a feebly condensed discharge through a rare gas at a pressure of about 10 mm Hg to which small amounts of nitrogen were added. Their results are impaired by systematic errors amounting to about 1 Å, which cannot be ascribed to the conditions of excitation. Thus, a reinvestigation of N I, especially in the infrared, has appeared desirable in order to improve and extend the present system of N I energy levels [Moore (1949)].

Light source

In a study of isotope shifts Holmes (1943) excited some infrared N I transitions in a discharge tube with external electrodes connected to a high frequency oscillator. As filling gas he used helium with an admixture of about one per cent nitrogen, the total pressure being 3–10 mm Hg. For the present investigation an electrodeless discharge excited in the coil of an oscillating circuit, link-coupled to a 9 Mc-per-sec generator, was preferred. The discharge tube was made of fused quartz with a cylindrical central part having a length of 12 cm and an inner diameter of 15 mm, conical end parts 3 cm in length, and vitreosil windows 40 mm in diameter, for end-on observation, all parts being fused together. Two side-tubes fused to the conical end pieces were connected through ground joints to a gas-circulating system. A mixture of neon and helium served as carrier gas, the appropriate pressure being 0.1–0.2 mm Hg. Traces of argon and xenon were occasionally admitted to obtain reference lines. Only a small nitrogen admixture was expedient in order not to have molecular bands covering up the atomic lines. A possible excess of nitrogen was extracted by means of a liquid-air-cooled charcoal trap. For a given filling gas the N I lines were strengthened more than the molecular bands by an increase in the high frequency power. By means of a pulsed power supply the peak power transferred to the discharge could be augmented while the average power was kept within the limit of about half a kilowatt set by the forced-air-cooled discharge tube. The equipment has already been described in detail by Minnhagen & Stigmark (1954). A maximum anode voltage of 8.5 kV was used for the pulsed power amplifier tube, Philips PB 3/800. Then, with a pulse duration of about 400 μsec and a repetition frequency of 500 pulses per sec, the average power supplied to the discharge tube amounted to about 0.5 kW, corresponding to a peak power of about 2.5 kW. For an anode voltage of about 8 kV and a nitrogen partial pressure of about 0.03 mm Hg the molecular band lines were generally weaker than the faintest N I lines observed (Plate II). Some NII lines appeared in the visible region, mainly belonging to the transitions $2p'$–$3p$, $3s$–$3p$, and $3s'$–$3p'$.

Spectrographs

The spectrum below 9800 Å was photographed by means of a Jarrell-Ash Wadsworth spectrograph, having a 21-foot Wood grating with 15000 lines per inch and a total of 80000 lines, giving a plate factor of 4.7–4.8 Å/mm in the infrared. The observations were extended to longer wavelengths by using a Wadsworth spectrograph, constructed by Lidén (1949), having a 21-foot Rowland grating with 10000 lines per inch and a total of 60000 lines, giving a plate factor of 7.4–7.5 Å/mm. The light source was focused end-on on the slit of the spectrograph. The spectrograms were taken on Eastman spectroscopic plates.

Spectrum lines

The new wavelengths in the long-wave region are given in Tables 1 and 2. They are weighted means of measurements on different spectrograms. 61 lines were measured on five or more spectrograms, 39 lines on three or four, and 18 lines on only one or two. The measurements were reduced by means of standards in the same diffraction order. As standards were used wavelengths in rare-gas spectra, interferometrically determined or computed from term values based on interferometric measurements. For wavelengths given to three decimal places in the second column of Tables 1 and 2 the error is estimated to be definitely less than 0.02 Å. The most reliable of previous measurements are quoted in the third column for comparison. The wave-numbers in the fourth column were derived by using Edlén's (1953) table of vacuum corrections.

The intensities are visual estimates, and the scale is consistent over limited regions only. The relative intensity for some transitions changed with the discharge conditions. As seen on Plate I the multiplets at 7899 Å and 8166 Å, designated as $3s'\,^2D$–$3p'\,^2P$ and $3s'\,^2D$–$5p\,^2D$ respectively, appear fairly strong when helium with only a trace of nitrogen is excited at moderate current densities. They are not strengthened in the same degree as the neighbouring multiplet $3s\,^4P$–$3p\,^4P$ when the nitrogen amount or the current density is increased. For comparison are also included on Plate I spectra excited with spark-generated high frequency pulses [Eriksson (1958)].

Table 1. Complete list of N I lines in the region 11 651–7 899 Å.

References to previous measurements: E = Edlén (1938); I = Ingram (1929); KS = Kamiyama & Sugiura (1940).

Intensity	Wavelength, Å		Wave-number, cm⁻¹		Combination
	measured	quoted	obs.	calc.*	
2	11 651.45	2.5 I	8 580.27	p^4	$2p^4\ {}^4P_{1/2}$–$3p\ {}^4S_{3/2}$
3	11 625.173	8.0 I	8 599.67	p^4	${}^4P_{3/2}$– ${}^4S_{3/2}$
4	11 566.114	4.8 I	8 643.58	p^4	${}^4P_{5/2}$– ${}^4S_{3/2}$
3	11 323.184		8 829.02	9.03	$3p\ {}^4D_{3/2}$–$4s\ {}^4P_{1/2}$
4	11 313.900	3.8 I	8 836.27	6.28	${}^4D_{5/2}$– ${}^4P_{3/2}$
2	11 294.242		8 851.65	1.64	${}^4D_{1/2}$– ${}^4P_{1/2}$
5	11 291.679	4.0 I	8 853.65	3.66	${}^4D_{7/2}$– ${}^4P_{5/2}$
3	11 266.210		8 873.67	3.68	${}^4D_{3/2}$– ${}^4P_{3/2}$
2	11 237.556		8 896.30	6.29	${}^4D_{1/2}$– ${}^4P_{3/2}$
3	11 227.076	7.5 I	8 904.60	4.59	${}^4D_{5/2}$– ${}^4P_{5/2}$
1	11 180.142		8 941.98	1.99	${}^4D_{3/2}$– ${}^4P_{5/2}$
2	10 884.60		9 184.78	4.80	$3p\ {}^4P_{5/2}$–$3d\ {}^4F_{7/2}$
1	10 879.19		9 189.34	9.37	${}^4P_{3/2}$– ${}^4F_{5/2}$
3	10 774.993		9 278.21	8.21	$3p\ {}^4P_{5/2}$–$3d\ {}^2F_{5/2}$
7	10 757.888	8.2 I	9 292.96	2.96	${}^4P_{5/2}$– ${}^4P_{5/2}$
4	10 730.510		9 316.67	6.67	${}^4P_{3/2}$– ${}^2F_{5/2}$
6	10 717.954		9 327.58	7.58	${}^4P_{5/2}$– ${}^4P_{3/2}$
8	10 713.550		9 331.42	1.42	${}^4P_{3/2}$– ${}^4P_{5/2}$
3	10 693.167		9 349.20	9.19	${}^4P_{5/2}$– ${}^2F_{7/2}$
8	10 653.034	3.6 I	9 384.43	4.43	${}^4P_{1/2}$– ${}^4P_{3/2}$
6	10 643.981		9 392.41	2.41	${}^4P_{3/2}$– ${}^4P_{1/2}$
5	10 623.177	3.3 I	9 410.80	0.80	${}^4P_{1/2}$– ${}^4P_{1/2}$
6	10 596.958		9 434.09	d'	$3p'\ {}^2F_{7/2}$–$3d'\ {}^2G_{9/2}$
5	10 591.905	1.8 I	9 438.59	d'	${}^2F_{5/2}$– ${}^2G_{7/2}$
5	10 563.328	0.2 KS	9 464.12	4.12	$3p\ {}^4P_{5/2}$–$3d\ {}^4D_{3/2}$
8	10 549.638	8.0 KS	9 476.40	6.40	${}^4P_{5/2}$– ${}^4D_{5/2}$
10	10 539.573	8.1 KS	9 485.45	5.45	${}^4P_{5/2}$– ${}^4D_{7/2}$
5	10 533.775	2.7 KS	9 490.67	0.68	${}^4P_{3/2}$– ${}^4D_{1/2}$
8	10 520.583	0.2 KS	9 502.57	2.58	${}^4P_{3/2}$– ${}^4D_{3/2}$
7	10 513.399	3.0 KS	9 509.07	9.07	${}^4P_{1/2}$– ${}^4D_{1/2}$
8	10 507.004	6.8 KS	9 514.85	4.86	${}^4P_{3/2}$– ${}^4D_{5/2}$
6	10 500.271	0.5 KS	9 520.96	0.97	${}^4P_{1/2}$– ${}^4D_{3/2}$
2	10 199.98	200.2 KS	9 801.25	1.24	$3p\ {}^4D_{7/2}$–$3d\ {}^4F_{5/2}$
3	10 166.79		9 833.25	3.24	${}^4D_{5/2}$– ${}^4F_{3/2}$

Table 1 (*continued*)

Intensity	Wavelength, Å		Wave-number, cm^{-1}		Combination
	measured	quoted	obs.	calc.*	
7	10 164.845	4.4 KS	9 835.13	5.13	$3p\ ^4D_{7/2}-3d\ ^4F_{7/2}$
8	10 147.255	7.3 KS	9 852.18	2.17	$^4D_{5/2}-\ ^4F_{5/2}$
7	10 128.280	8.5 KS	9 870.64	0.64	$^4D_{3/2}-\ ^4F_{3/2}$
13	10 114.644	5.1 KS	9 883.95	*d*	$^4D_{7/2}-\ ^4F_{9/2}$
12	10 112.483	3.0 KS	9 886.06	6.06	$^4D_{5/2}-\ ^4F_{7/2}$
11	10 108.893	9.2 KS	9 889.57	9.57	$^4D_{3/2}-\ ^4F_{5/2}$
10	10 105.130	5.4 KS	9 893.25	3.25	$^4D_{1/2}-\ ^4F_{3/2}$
4	10 054.259		9 943.31	3.29	$3p\ ^4D_{7/2}-3d\ ^4P_{5/2}$
5	10 017.822	8.1 KS	9 979.47	9.47	$^4D_{5/2}-\ ^2F_{5/2}$
5	10 003.055	3.7 KS	9 994.21	4.22	$^4D_{5/2}-\ ^4P_{5/2}$
4	9 997.750	8.4 KS	9 999.51	9.52	$^4D_{7/2}-\ ^2F_{7/2}$
3	9 980.424	0.8 KS	10 016.87	6.87	$^4D_{3/2}-\ ^2F_{5/2}$
3	9 965.736	5.4 KS	10 031.63	1.62	$^4D_{3/2}-\ ^4P_{5/2}$
4	9 947.066	6.7 KS	10 050.46	0.45	$^4D_{5/2}-\ ^2F_{7/2}$
5	9 931.474	0.8 KS	10 066.24	6.24	$^4D_{3/2}-\ ^4P_{3/2}$
2	9 909.220	8.0 KS	10 088.85	8.85	$^4D_{1/2}-\ ^4P_{3/2}$
0	9 905.54		10 092.60	2.61	$^4D_{3/2}-\ ^4P_{1/2}$
3	9 883.369	2.8 KS	10 115.23	5.22	$^4D_{1/2}-\ ^4P_{1/2}$
6	9 872.145	1.3 KS	10 126.73	6.73	$3p\ ^4D_{7/2}-3d\ ^4D_{5/2}$
9	9 863.330	2.4 KS	10 135.79	5.78	$^4D_{7/2}-\ ^4D_{7/2}$
6	9 834.621	3.6 KS	10 165.37	5.38	$^4D_{5/2}-\ ^4D_{3/2}$
7	9 822.748	1.9 KS	10 177.66	7.66	$^4D_{5/2}-\ ^4D_{5/2}$
4	9 814.000	3.0 KS	10 186.73	6.71	$^4D_{5/2}-\ ^4D_{7/2}$
5	9 810.003	09.0 KS	10 190.88	0.88	$^4D_{3/2}-\ ^4D_{1/2}$
5	9 798.564	6.5 KS	10 202.78	2.78	$^4D_{3/2}-\ ^4D_{3/2}$
4	9 788.286	7.1 KS	10 213.49	3.49	$^4D_{1/2}-\ ^4D_{1/2}$
4	9 786.770	3.9 KS	10 215.07	5.06	$^4D_{3/2}-\ ^4D_{5/2}$
4	9 776.885	6.5 KS	10 225.40	5.39	$^4D_{1/2}-\ ^4D_{3/2}$
1	9 694.01		10 312.82	*d*	$3p\ ^4D_{5/2}-3d\ ^2D_{5/2}$
1	9 464.23	8.2 KS	10 563.20		$3p\ ^2S_{1/2}-4s\ ^2P_{1/2}$
10	9 460.676	0.0 I	10 567.17	7.17	$3s\ ^2P_{3/2}-3p\ ^2D_{3/2}$
15	9 392.789	2.80 E	10 643.54	*p*	$^2P_{3/2}-\ ^2D_{5/2}$
14	9 386.805	6.79 E	10 650.33	0.33	$^2P_{1/2}-\ ^2D_{3/2}$
8	9 208.001	8.2 KS	10 857.14	7.14	$3s'\ ^2D_{3/2}-3p'\ ^2D_{3/2}$
3	9 207.59		10 857.63	7.64	$^2D_{5/2}-\ ^2D_{3/2}$
3	9 187.84		10 880.97	0.93	$^2D_{3/2}-\ ^2D_{5/2}$
9	9 187.449	7.5 KS	10 881.43	1.43	$^2D_{5/2}-\ ^2D_{5/2}$

Table 1 (*continued*)

Intensity	Wavelength, Å		Wave-number, cm^{-1}		Combination
	measured	quoted	obs.	calc.*	
10	9 060.472	1.3 KS	11 033.92		$3p\ {}^2S_{1/2}-3d\ {}^2P_{3/2}$
12	9 049.890	51.0 KS	11 046.83	6.83	$3s'\ {}^2D_{3/2}-3p'\ {}^2F_{5/2}$
5	9 049.47		11 047.34	7.33	${}^2D_{5/2}-\ \ {}^2F_{5/2}$
13	9 045.878	6.9 KS	11 051.73	p'	${}^2D_{5/2}-\ \ {}^2F_{7/2}$
9	9 028.918	30.5 KS	11 072.49		$3p\ {}^2S_{1/2}-3d\ {}^2P_{1/2}$
3	9 022.183		11 080.75		
3	9 021.236		11 081.91		
2	9 020.68		11 082.60		
4	9 019.432		11 084.13		
9	8 747.357	7.35 E	11 428.89	8.87	$3s\ {}^4P_{5/2}-3p\ {}^4D_{3/2}$
10	8 728.894	8.88 E	11 453.06	3.05	${}^4P_{3/2}-\ \ {}^4D_{1/2}$
14	8 718.826	8.82 E	11 466.29	6.27	${}^4P_{5/2}-\ \ {}^4D_{5/2}$
15	8 711.704	1.69 E	11 475.66	5.66	${}^4P_{3/2}-\ \ {}^4D_{3/2}$
14	8 703.248	3.24 E	11 486.81	6.81	${}^4P_{1/2}-\ \ {}^4D_{1/2}$
14	8 686.149	6.13 E	11 509.42	9.42	${}^4P_{1/2}-\ \ {}^4D_{3/2}$
16	8 683.401	3.38 E	11 513.06	3.06	${}^4P_{3/2}-\ \ {}^4D_{5/2}$
17	8 680.283	0.24 E	11 517.20	7.20	${}^4P_{5/2}-\ \ {}^4D_{7/2}$
14	8 655.869	5.88 E	11 549.68	9.66	$3s\ {}^2P_{3/2}-3p\ {}^2P_{1/2}$
16	8 629.238	9.24 E	11 585.33	5.33	${}^2P_{3/2}-\ \ {}^2P_{3/2}$
15	8 594.005	4.01 E	11 632.82	2.82	${}^2P_{1/2}-\ \ {}^2P_{1/2}$
14	8 567.735	7.74 E	11 668.49	8.49	${}^2P_{1/2}-\ \ {}^2P_{3/2}$
13	8 242.393	2.34 E	12 129.06	9.07	$3s\ {}^4P_{5/2}-3p\ {}^4P_{3/2}$
13	8 223.140	3.07 E	12 157.46	7.47	${}^4P_{3/2}-\ \ {}^4P_{1/2}$
15	8 216.345	6.28 E	12 167.52	7.53	${}^4P_{5/2}-\ \ {}^4P_{5/2}$
11	8 210.715	0.64 E	12 175.86	5.86	${}^4P_{3/2}-\ \ {}^4P_{3/2}$
7	8 201.766		12 189.14	9.14	$3s'\ {}^2D_{3/2}-5p\ {}^2D_{3/2}$
2	8 201.43		12 189.64	9.64	${}^2D_{5/2}-\ \ {}^2D_{3/2}$
10	8 200.363	0.31 E	12 191.23	1.23	$3s\ {}^4P_{1/2}-3p\ {}^4P_{1/2}$
13	8 188.023	7.95 E	12 209.60	9.62	${}^4P_{1/2}-\ \ {}^4P_{3/2}$
13	8 184.867	4.80 E	12 214.31	4.32	${}^4P_{3/2}-\ \ {}^4P_{5/2}$
1	8 174.50		12 229.81	9.86	$3p\ {}^2P_{3/2}-5s\ {}^2P_{1/2}$
2	8 166.51		12 241.77	1.68	$3s'\ {}^2D_{3/2}-5p\ {}^2D_{5/2}$
8	8 166.235		12 242.18	2.18	${}^2D_{5/2}-\ \ {}^2D_{5/2}$

Table 1 (*continued*)

Intensity	Wavelength, Å		Wave-number, cm^{-1}		Combination
	measured	quoted	obs.	calc.*	
1	8 150.66		12 265.57	5.53	$3p\ ^2P_{1/2}$–$5s\ ^2P_{1/2}$
3	8 129.170		12 298.00	8.02	$^2P_{3/2}$– $^2P_{3/2}$
2	8 105.631		12 333.71	3.69	$^2P_{1/2}$– $^2P_{3/2}$
7	7 915.419		12 630.10	p'	$3s'\ ^2D_{3/2}$–$3p'\ ^2P_{1/2}$
3	7 899.27		12 655.92	5.88	$^2D_{3/2}$– $^2P_{3/2}$
8	7 898.985		12 656.37	6.38	$^2D_{5/2}$– $^2P_{3/2}$

* A configuration symbol in this column indicates that the level was calculated from only this line.

Table 2. N I lines in the visible region used for the calculation of level values.

References to previous measurements: DW = Duffendack & Wolfe (1929); E = Edlén (1938); R = Ryde (1927).

Intensity	Wavelength, Å		Wave-number, cm^{-1}		Combination
	measured	quoted	obs.	calc.	
16	7468.309	8.29 E	13 386.23	6.22	$3s\ ^4P_{5/2}$–$3p\ ^4S_{3/2}$
15	7442.299	2.28 E	13 433.01	3.01	$^4P_{3/2}$– $^4S_{3/2}$
14	7423.639	3.63 E	13 466.77	6.77	$^4P_{1/2}$– $^4S_{3/2}$
5	5411.881	2.02 R	18 472.73	2.73	$3p\ ^2P_{3/2}$–$3s''\ ^2S_{1/2}$
4	5401.450	1.41 R	18 508.40	8.40	$^2P_{1/2}$– $^2S_{1/2}$
3	4113.972	4.00 DW	24 300.55	0.49	$3s\ ^2P_{3/2}$–$3p'\ ^2D_{3/2}$
8	4109.959	9.98 DW	24 324.28	4.28	$^2P_{3/2}$– $^2D_{5/2}$
7	4099.951	9.94 DW	24 383.65	3.65	$^2P_{1/2}$– $^2D_{3/2}$

Energy levels

The new wavelengths have been used to calculate relative level values. Table 3 contains all quartet levels of the configurations $3s$, $2p^4$, $3p$, $4s$, and $3d$. Furthermore, the doublet levels $3d\,^2F_{7/2,\,5/2}$ and $3d\,^2D_{5/2}$ are attached to the quartet system through infrared intercombination lines. The high doublet levels given in Table 4 compose a separate group of accurately connected levels. Each group is believed to be internally consistent to within 0.03 cm^{-1}. Recalculated wave-numbers are included in Tables 1 and 2.

Table 3. N I, quartet levels, including $3d\,{}^2F_{7/2,\,5/2}$ and $3d\,{}^2D_{5/2}$.

Configuration	Symbol	Level, cm⁻¹	
$2s^2\ 2p^3$	$2p^3\ {}^4S_{3/2}$	0.00	
$2s^2\ 2p^2(^3P)3s$	$3s\ {}^4P_{5/2}$	83 364.52	46.79
	${}^4P_{3/2}$	83 317.73	33.76
	${}^4P_{1/2}$	83 283.97	
$2s\ 2p^4$	$2p^4\ {}^4P_{5/2}$	88 107.16	−43.91
	${}^4P_{3/2}$	88 151.07	−19.40
	${}^4P_{1/2}$	88 170.47	
$2s^2\ 2p^2(^3P)3p$	$3p\ {}^4D_{7/2}$	94 881.72	50.93
	${}^4D_{5/2}$	94 830.79	37.40
	${}^4D_{3/2}$	94 793.39	22.61
	${}^4D_{1/2}$	94 770.78	
	${}^4P_{5/2}$	95 532.05	38.46
	${}^4P_{3/2}$	95 493.59	18.39
	${}^4P_{1/2}$	95 475.20	
	${}^4S_{3/2}$	96 750.74	
$2s^2\ 2p^2(^3P)4s$	$4s\ {}^4P_{5/2}$	103 735.38	68.31
	${}^4P_{3/2}$	103 667 07	44.65
	${}^4P_{1/2}$	103 622.42	
$2s^2\ 2p^2(^3P)3d$	$3d\ {}^4F_{9/2}$	104 765.67	48.82
	${}^4F_{7/2}$	104 716.85	33.89
	${}^4F_{5/2}$	104 682.96	18.93
	${}^4F_{3/2}$	104 664.03	
	${}^4D_{7/2}$	105 017.50	9.05
	${}^4D_{5/2}$	105 008.45	12.28
	${}^4D_{3/2}$	104 996.17	11.90
	${}^4D_{1/2}$	104 984.27	
	${}^4P_{5/2}$	*104 825.01	−34.62
	${}^4P_{3/2}$	*104 859.63	−26.37
	${}^4P_{1/2}$	*104 886.00	
	${}^2F_{7/2}$	104 881.24	70.98
	${}^2F_{5/2}$	104 810.26	
	${}^2D_{5/2}$	105 143.61	

* Designations originally suggested by Edlén on the basis of observations by Worley (1945) of the transitions to the ground level.

Table 4. N I, internally connected group of doublet levels.

Configuration	Symbol	Level, cm⁻¹	
$2s^2\ 2p^3$	$2p^3\ {}^2D_{5/2}$	19 224.26	−8.86
	${}^2D_{3/2}$	19 233.12	
	${}^2P_{3/2}$	28 839.38	0.28
	${}^2P_{1/2}$	28 839.10	
$2s^2\ 2p^2(^3P)3s$	$3s\ {}^2P_{3/2}$	86 220.77	83.16
	${}^2P_{1/2}$	86 137.61	
$2s^2\ 2p^2(^3P)3p$	$3p\ {}^2D_{5/2}$	96 864.31	76.37
	${}^2D_{3/2}$	96 787.94	
	${}^2P_{3/2}$	97 806.10	35.67
	${}^2P_{1/2}$	97 770.43	
$2s^2\ 2p^2(^1D)3s$	$3s'\ {}^2D_{5/2}$	99 663.62	−0.50
	${}^2D_{3/2}$	99 664.12	
$2s^2\ 2p^2(^3P)5s$	$5s\ {}^2P_{3/2}$	110 104.12	68.16
	${}^2P_{1/2}$	110 035.96	
$2s^2\ 2p^2(^1D)3p$	$3p'\ {}^2F_{7/2}$	*110 715.35	4.40
	${}^2F_{5/2}$	*110 710.95	
	${}^2D_{5/2}$	110 545.05	23.79
	${}^2D_{3/2}$	110 521.26	
	${}^2P_{3/2}$	112 320.00	25.78
	${}^2P_{1/2}$	112 294.22	
$2s^2\ 2p^2(^3P)5p$	$5p\ {}^2D_{5/2}$	*111 905.80	52.54
	${}^2D_{3/2}$	*111 853.26	
$2s^2\ 2p^2(^1S)3s$	$3s''\ {}^2S_{1/2}$	*116 278.83	
$2s^2\ 2p^2(^1D)3d$	$3d'\ {}^2G_{9/2}$	*120 149.44	−0.10
	${}^2G_{7/2}$	*120 149.54	

* New levels.

Table 5. Observed and calculated vacuum wavelengths for some N I lines in the region 1 745–951 Å.

Combination	λ_{calc}, Å	λ Edlén & Eriksson	λ Wilkinson (1955)	λ More & Rieke (1936)	λ Weber & Watson (1936)	λ Boyce & Rieke (1935)
$2p^3\ {}^2P_{3/2}-3s\ {}^2P_{1/2}$	1745.255	5.249	5.246		5.255	5.246
${}^2P_{1/2}-\ {}^2P_{1/2}$	1745.246					
${}^2P_{3/2}-\ {}^2P_{3/2}$	1742.725	2.724	2.724		2.733	2.734
${}^2P_{1/2}-\ {}^2P_{3/2}$	1742.717					
$2p^3\ {}^2D_{3/2}-3s\ {}^2P_{1/2}$	1494.668	4.668	4.673	4.672	4.668	4.669
${}^2D_{3/2}-\ {}^2P_{3/2}$	1492.812	2.811	2.824			
${}^2D_{5/2}-\ {}^2P_{3/2}$	1492.615	2.615	2.624		2.634	2.630
$2p^3\ {}^2P_{3/2}-3s'\ {}^2D_{5/2}$	1411.946	1.939	1.948		1.935	
${}^2P_{3/2}-\ {}^2D_{3/2}$	1411.936					
${}^2P_{1/2}-\ {}^2D_{3/2}$	1411.930					
$2p^3\ {}^2P_{3/2}-3d\ {}^2F_{5/2}$	1316.294		6.287			
${}^2P_{3/2}-\ {}^2D_{5/2}$	1310.543		0.548	0.546	0.569	
$2p^3\ {}^2D_{3/2}-3s'\ {}^2D_{5/2}$	1243.309		3.309			3.297
${}^2D_{3/2}-\ {}^2D_{3/2}$	1243.302					
${}^2D_{5/2}-\ {}^2D_{5/2}$	1243.173		3.179		3.141	3.170
${}^2D_{5/2}-\ {}^2D_{3/2}$	1243.165					
$2p^3\ {}^4S_{3/2}-3s\ {}^4P_{1/2}$	1200.711	0.711	0.708	0.719	0.693	0.706
${}^4S_{3/2}-\ {}^4P_{3/2}$	1200.225	0.225	0.226	0.217	0.215	0.220
${}^4S_{3/2}-\ {}^4P_{5/2}$	1199.551	9.551	9.551	9.552	9.557	9.547
$2p^3\ {}^2D_{3/2}-3d\ {}^4F_{5/2}$	1170.277		0.276			
${}^2D_{5/2}-\ {}^4F_{7/2}$	1169.692		9.692			
${}^2D_{3/2}-\ {}^2F_{5/2}$	1168.536	8.537	8.537	8.543		
${}^2D_{5/2}-\ {}^2F_{5/2}$	1168.415	8.414				
${}^2D_{3/2}-\ {}^4P_{5/2}$	1168.335		8.334			
${}^2D_{5/2}-\ {}^4P_{5/2}$	1168.214					
${}^2D_{5/2}-\ {}^2F_{7/2}$	1167.447	7.454	7.450	7.442	7.454	
${}^2D_{5/2}-\ {}^2D_{5/2}$	1163.882		3.884	3.870	3.858	
$2p^3\ {}^2P_{3/2}-3s''\ {}^2S_{1/2}$	1143.649	3.649				
${}^2P_{1/2}-\ {}^2S_{1/2}$	1143.645					
$2p^3\ {}^4S_{3/2}-2p^4\ {}^4P_{5/2}$	1134.982	4.979	4.988	4.977	4.980	4.980
${}^4S_{3/2}-\ {}^4P_{3/2}$	1134.416	4.417	4.426	4.415	4.416	4.419
${}^4S_{3/2}-\ {}^4P_{1/2}$	1134.167	4.168	4.176	4.162	4.169	4.171

Table 5 (*continued*)

Combination	λ_{calc}, Å	λ Wilkinson (1955)	Combination	λ_{calc}, Å	λ Wilkinson (1955)
$2p^3\ {}^4S_{3/2}$–$4s\ {}^4P_{1/2}$	965.042		$2p^3\ {}^4S_{3/2}$–$3d\ {}^4P_{5/2}$	953.971	
${}^4S_{3/2}$– ${}^4P_{3/2}$	964.626	4.626	${}^4S_{3/2}$– ${}^4P_{3/2}$	953.656	3.658
${}^4S_{3/2}$– ${}^4P_{5/2}$	963.991	3.991	${}^4S_{3/2}$– ${}^4P_{1/2}$	953.416	3.415
			${}^4S_{3/2}$– ${}^4D_{1/2}$	952.524	2.522
$2p^3\ {}^4S_{3/2}$–$3d\ {}^4F_{3/2}$	955.438		${}^4S_{3/2}$– ${}^4D_{3/2}$	952.416	2.414
${}^4S_{3/2}$– ${}^4F_{5/2}$	955.265		${}^4S_{3/2}$– ${}^4D_{5/2}$	952.304	2.304
${}^4S_{3/2}$– ${}^2F_{5/2}$	954.105		${}^4S_{3/2}$– ${}^2D_{5/2}$	951.080	

Table 6. Observed and calculated wavelengths for some forbidden N I lines.

Combination	λ_{calc}, Å	λ Bowen (1955)	Combination	λ_{calc}, Å	λ Janin (1946)
$2p^3\ {}^4S_{3/2}$–$2p^3\ {}^2D_{5/2}$	5200.31	0.41 ± 0.04	$2p^3\ {}^4S_{3/2}$–$2p^3\ {}^2P_{1/2}$	3466.52	6.63 ± 0.05
${}^4S_{3/2}$– ${}^2D_{3/2}$	5197.92	7.94 ± 0.07	${}^4S_{3/2}$– ${}^2P_{3/2}$	3466.49	

Observations in the vacuum region

Some plates taken by Edlén in 1937 using the 2-meter normal incidence vacuum spectrograph at the Massachusetts Institute of Technology [Compton & Boyce (1934)] show self-reversed N I lines with sharp absorption lines, the light source being a spark in nitrogen at half an atmosphere pressure. Some of these lines were previously measured by Edlén and used for a calculation of the deep levels quoted by Nicolet (1938). The region 1745–1412 Å has now been measured in the first order against Fe II standards [from Edlén (1942) and Wilkinson (1957)] and the region 1201–1134 Å in the second order against the hydrogen L_α absorption line [1215.670 Å] and first order Fe II standards [from Burns & Walters (1931) and Edlén (1942)]. The limits of error in these wavelength measurements are estimated to be about 0.003 Å and 0.002 Å respectively.

The new wavelength values and all previous vacuum-ultraviolet measurements of interest for the connexion of the deep levels have been collected in Table 5. The high levels in Table 3 have been referred to the ground level with an accuracy of 0.1 cm^{-1} by means of the combinations $2p^3\,{}^4S$–$3s\,{}^4P$ and $2p^3\,{}^4S$–$2p^4\,{}^4P$. The deep doublet terms $2p^3\,{}^2D$ and $2p^3\,{}^2P$ have been tied up with the high doublet group in Table 4 with about the same accuracy by means of the combinations with $3s\,{}^2P$ and $3s''\,{}^2S$. Combinations between the deep doublet levels and levels in Table 3 (listed in Tables 5 and 6) allow the doublet system in Table 4 to be referred to the ground level with an accuracy of about 0.3 cm^{-1}.

Provisional vacuum-ultraviolet standards of wavelength

Wavelengths calculated from the level values given in Tables 3 and 4 are inserted in Table 5. Their uncertainty ranges from 0.003 Å at 1745 Å to 0.001 Å at 951 Å. Owing to the close structure of the deep doublet terms the use of some lines as standards is impaired by blends. The tabulated interval value for $2p^3\,{}^2P$ is close to the experimental uncertainty and therefore rather tentative. The wavelengths for the combinations of the deep doublet terms with $3d$ and $4s$ levels need to be improved by observations in the lead-sulfide region.

Dr G. Herzberg (National Research Council, Ottawa) in a private communication to Professor B. Edlén, which was received during the final preparation of the manuscript of the present article, reports the wavelength values 1200.7113 Å, 1200.2238 Å, and 1199.5490 Å. The agreement with the calculated values in Table 5 is very close, the deviations being only 0.000 Å, -0.001 Å, and -0.002 Å, respectively.

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Tryckt den 15 april 1958

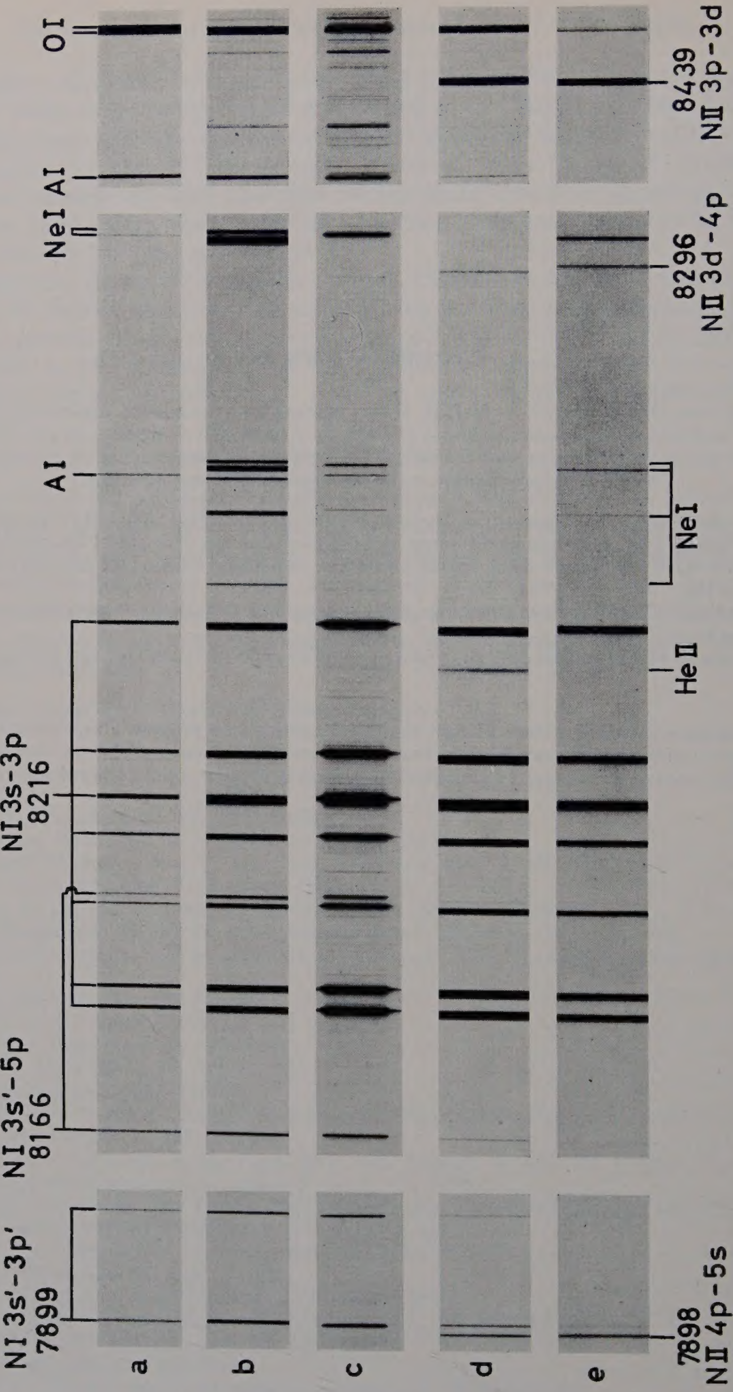
Uppsala 1958. Almqvist & Wiksells Boktryckeri AB

Description of Plates I–II

I. Spectrograms obtained with a 21-foot Wood grating in a stigmatic mounting (plate factor 4.8 Å/mm) and an electrodeless discharge excited by means of a 9 Mc-per-sec generator (*a*, *b*, *c*) or a 0.7 Mc-per-sec spark-generated circuit (*d*, *e*), showing the dependence of relative intensities in the nitrogen spectrum on peak power and gas mixture.

a. Anode voltage 3 kV; continuous discharge in helium (0.2 mm Hg) with only a trace of nitrogen.
b. Anode voltage 3 kV; continuous discharge in neon (0.2 mm Hg) with about ten per cent nitrogen.
c. Anode voltage 8 kV; pulsed discharge in a mixture of helium + neon (0.2 mm Hg) and nitrogen (0.06 mm Hg).
d. Spark voltage 27 kV; pulsed discharge in a mixture of helium (0.05 mm Hg) and nitrogen (0.06 mm Hg).
e. Spark voltage 36 kV; pulsed discharge in a mixture of neon (0.1 mm Hg) and nitrogen (0.06 mm Hg).

II. Spectrograms obtained with a 21-foot Rowland grating in a stigmatic mounting (plate factor 7.5–7.4 Å/mm) and an electrodeless discharge in a mixture of neon (0.1 mm Hg) and nitrogen (0.03 mm Hg) excited by means of a pulsed 9 Mc-per-sec generator, the anode voltage being 7–8 kV.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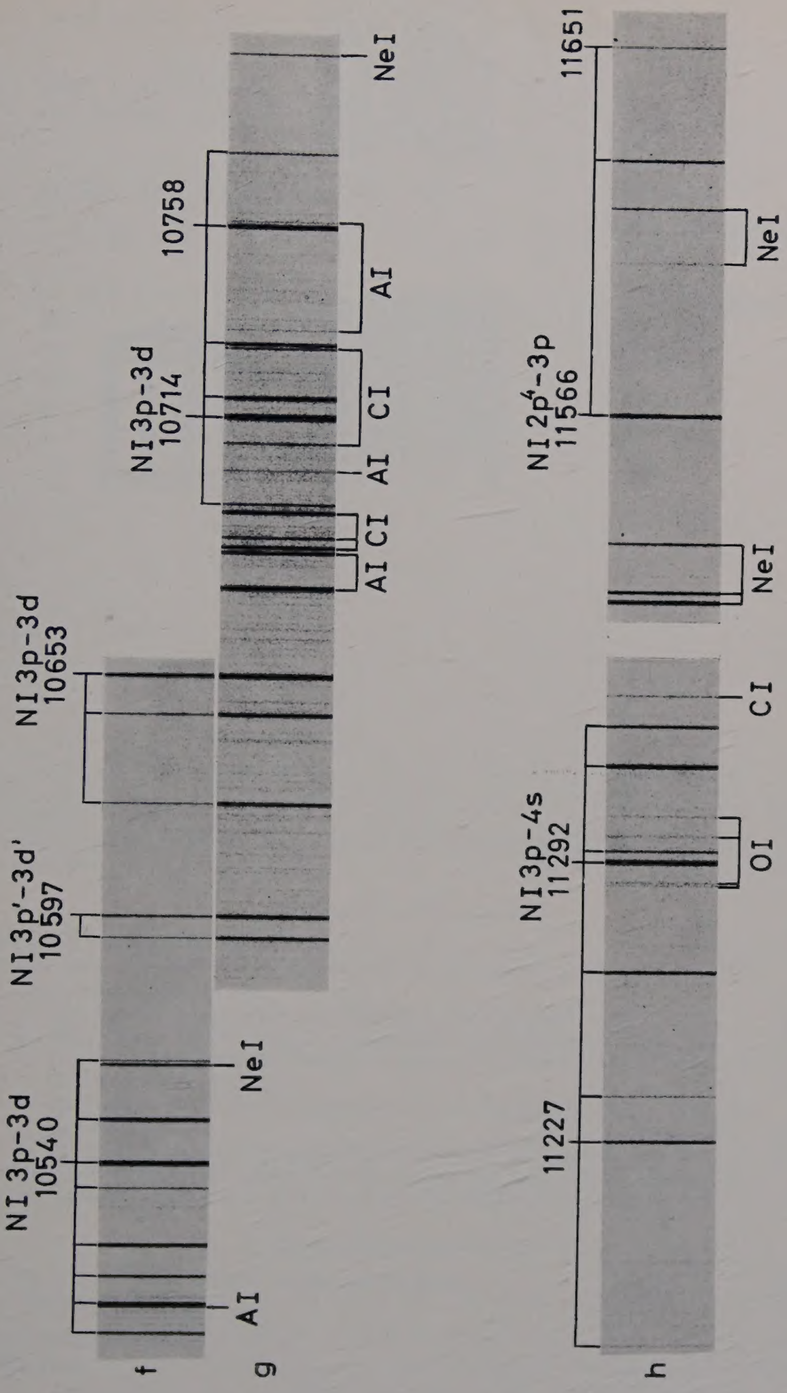
NII 3p-3d

Plate II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